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THE INSTITUTION OF PRODUCTION ENGINEERS

JOURNAL

(May, 1946, Vol. XXV, No. 5, Ed. A)

Contents:

"TECHNICAL CONSIDERATIONS AFFECTING THE PRODUCTION AND USE OF STEEL CASTINGS"

by

A. B. LLOYD, A.M.I.P.E.

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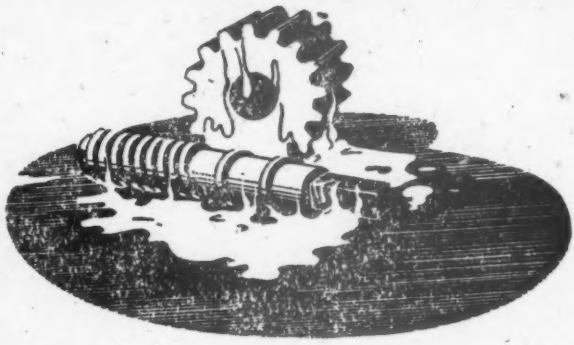

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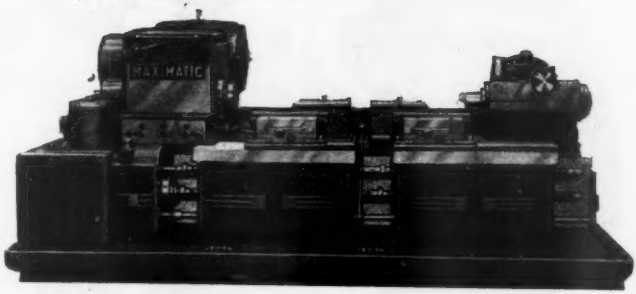

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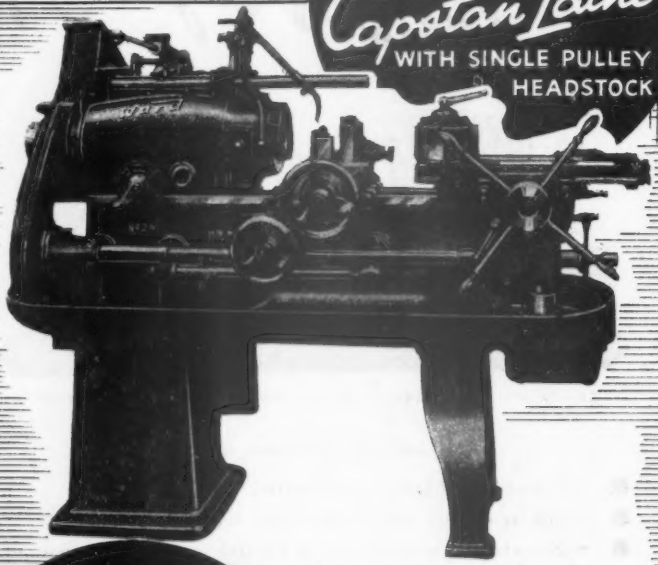

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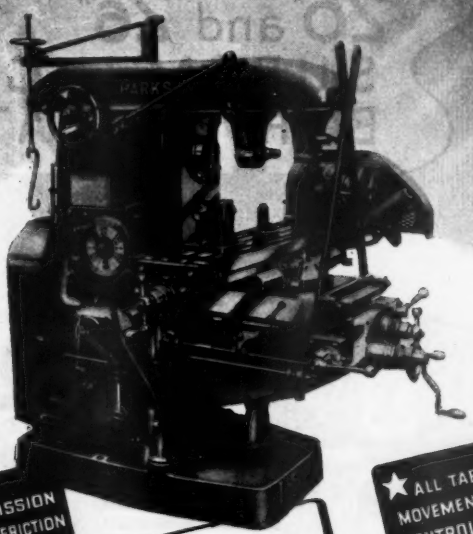

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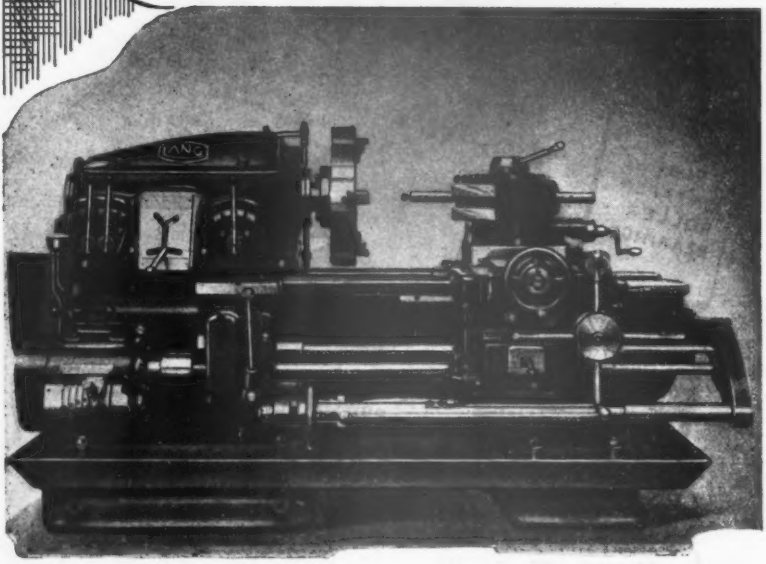

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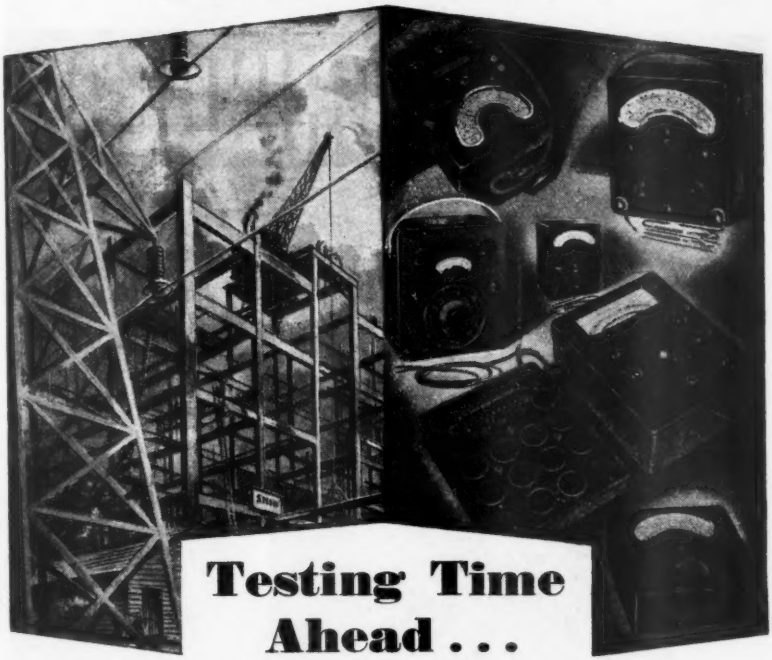

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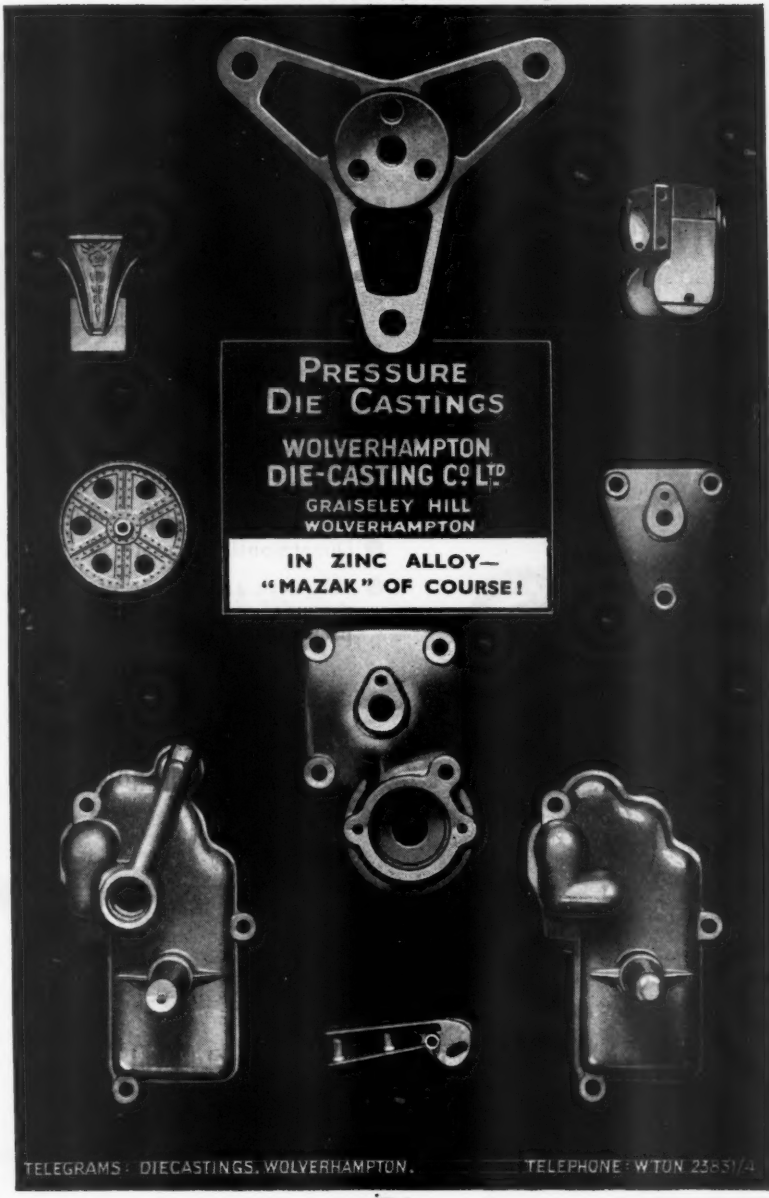
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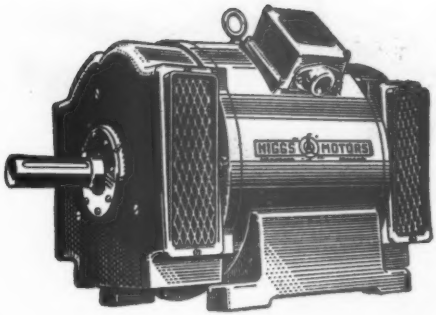

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INSTITUTION NOTES

May, 1946

May Meetings

4th Manchester Section. Visit to Messrs. A. V. Roe, Ltd., Woodford Works and Aerodrome.

11th Yorkshire Graduate Section. Annual Luncheon, Great Northern Station Hotel, Leeds, at 1-00 p.m., to be followed by the Annual General Meeting at 2-15 p.m., and a "Film Afternoon," when the following sound films will be shown, by permission of the Ministry of Information Regional Film Officer: "Operation P.L.U.T.O."; "The Bailey Bridge"; "Radar"; "Airscrew" (manufacture of aircraft propellor blades); "Date with a Tank"; "Silent and Certain" (working principles of the synchromesh gear box); "Precision Makes Perfect"; "Fabrication of Refrigerators."

15th Preston Section. Annual General Meeting will be held at 7-00 p.m., at the Star Paper Mill, Feniscowles, Blackburn, followed by a visit to the Star Paper Mill.

20th Derby Sub-Section. Annual General Meeting will be held at 6-30 p.m., at the School of Art, Green Lane, Derby, to be followed by a short film entitled "The Mosquito," by courtesy of De Havilland Aircraft Co., Ltd.

23rd Wolverhampton Section. A lecture will be given by R. E. Reason, Esq., on "The Measurement of Surface Texture," at the Dudley and Staffordshire Technical College, Dudley, at 6-30 p.m.

May Committee Meetings

10th Finance and General Purposes Committee, at 2-30 p.m., in the Temporary Committee Room, 36, Portman Square, London, W.1.

21st Education Committee, at 10-30 a.m., at the Queen's Hotel, Birmingham.

21st Membership Committee, at 12-30 p.m., at the Queen's Hotel, Birmingham.

May Committee Meetings—*Cont.*

— Research Committee, at 11-45 a.m., at Loughborough College, Lougborough, Leics.

Technical and Publications Committee meets every Wednesday at 5-30 p.m., in the TEMPORARY Committee Room, 36, Portman Square, London, W.1.

Until further notice, meetings of the Finance and General Purposes Committee, the Technical and Publications Committee, and the London Section Committee will be held in the TEMPORARY Committee Room at 36, Portman Square, London, W.1. All correspondence is still to be addressed to No. 10, Seymour Street, London, W.1.

Council Meeting

The next meeting of the Council will be held on Friday, 28th June, 1946, at 11-00 a.m., preceded by an Extraordinary General Meeting at 10-30 a.m., at the Institution of Civil Engineers, Great George Street, London, S.W.1.

Personal

Mr. W. H. Denholm, M.B.E., M.I.P.E., has been appointed Assistant Controller of the Mechanical Engineering Branch (Econ. 11), at Headquarters, Economics Division, with the B.A.O.R. at Minden.

Combined Intelligence Objectives Sub-Committee Reports

These reports, which are issued by H.M. Stationery Office, are now available. Those listed below* have been selected by the Technical and Publications Committee as being of particular interest to Production Engineers, and are available for reference at Headquarters, but additional copies may be obtained from the Stationery Office, at various prices.

Further selections will be published each month.

Synthetic Lubricating Oils. File No. XXX—5.

German Optical Production. File No. XXIX—52.

Machine Used by Carl Zeiss, Jena, to Grind Aspheric Lens Surfaces. File No. XXVII—24.

Combined Intelligence Objectives Sub-Committee Reports—*Cont.*

German Steel Foundry Methods. File No. XXVI—86.

Mahle K.G. (Piston Plant) Bad Cannstatt. File No. XXVI—84.

Fabrication of Plastics I.G. Farbenindustrie, Wolfen. File No. XXVII—16.

Steel Forging Industry of Germany. File No. XXVI—69.

Internal Combustion Engines. File No. XXXI—78.

Metallurgical High Lights in the Recent Manufacture of Rolled Steel Plates and Sheets in Germany. File No. XXVII—29.

Low Tension Ignition. File No. XXIX—53.

Lubricants Manufactured and Used by Zeiss in Jena. File No. XXIX—40.

Recoilless Guns Development of Rheinmetall-Borsigg. File No. XXVII—27.

German Clock and Watch Industry. File No. XXVII—5.

Production Statistics, German Steel Industry 1943 and 1944. File No. XXVIII—54.

German Die-Casting Plants. File No. XXVII—76.

Horten Tailless Aircraft. File No. XIX—2.

Optical Grinding and Centering Equipment used by Carl Zeiss, Jena. File No. XXVII—23.

The Production of Binoculars by Zeiss. File No. XXIX—42.

Munich Technical High School. Final Report No. 118.

Rotary Air Compressors Built by Demag A.G., Duisburg. File No. XXVI—77.

I.G. Farbenindustrie Laboratory, Leverkusen. File No. XXV—34.

Metal Fabrication at Mansfeld A.G. Kupfer Und Messing Werke Hettstedt. File No. XXIX—18.

German Spring Making Industry. Final Report No. 181.

Visit to Germany—Electric Power. Final Report No. 38.

Survey of Production Techniques used in the German Aircraft Industry. File No. XXV—42.

Combined Intelligence Objectives Sub-Committee Reports—*Cont.*

Production of Optical Glass in Germany and France. File No. XXIX—41.

German Oil Seal Manufacturers. Final Report No. 164.

Gas Turbine Development B.M.W., Junkers, Daimler Benz. File No. XXIV—6.

Investigation of German Plastics Plants. File No. XXIX—62.

Engine Works—M.W.M., Mannheim ; Daimler Benz, Rothenbach ; Brown Boveri Co., Mannheim. File No. XXVI—4—26, 29.

German Mechanical Engineering Industry. File No. XXV—36.

Dachs 1, Lubricating Oil Plant, Porta, Germany. File No. XXVI—87.

Light Metal Production and Development for Aircraft I.G Farbenindustrie, Bitterfeld. File No. XXVI—60.

German Aircraft Maintenance. File No. XXV—45.

Cellulose Plastics Industry in Germany. Final Report No. 185.

Aluminium Woerwerke, Erbtwerke, Gravenbroich. File No. XXII—4.

Caproni-Campini Aircraft and Allied Developments in Italy. File No. XII—24.

Gas Turbine and Jet Propulsion Work in Paris. File No. IV–I—8.

German Railroad Technical Development. File No. XXIV—17.

German Locomotive Industry. File No. XXV—35.

Diesel Engine Research and Development in Germany. File No. XXV—28.

Friedrich-Alfred-Hutte (Metallurgy) at Rheinhausen. File No. XXIV—10.

The German Abrasive Industry. Final Report No. 113.

Robert Bosch (Metallurgy), Stuttgart and Fuerbach. File No. XXVII—91.

Die Staatliche Materialprufungsanstalt an der Technische Hochschule (Fuels and Lubricants). File No. XXV—24.

Light Steel Building Products. File No. XXVI—22.

Combined Intelligence Objectives Sub-Committee Reports—*Cont.*

Electronic Valve (Tube) Factories Helmbrechts and Minden. File No. XXIV—26, 27.

Klein, Schanglin and Becker A.G. Hydraulic Couplings and Torque Converters. File No. XXVI—66.

I.G. Farbenindustrie-Oppau Works (Metallurgy) Ludwigshafen. File No. XXIV—12.

German Activities in the French Aircraft Industry. File No. XVII—1.

The Horten Tailless Aircraft. File No. XXIII—6.

Books Received.

The Law of Trade Unions, by H. Samuels, M.A. Published by Stevens and Sons, Ltd., London. Price 5/- net.

Optical Instruments in Engineering, by Sydney H. Hemsley, B.Sc. (Hons.), M.Amer.I.E.E., A.M.I.E.E. Published by Paul Elek, Ltd., London. Price 7/6 net.

Pressure Welding of Light Alloys Without Fusion, by R. F. Tylecote, M.A., M.Sc. (British Welding Research Association, 5/- net.)

This report describes the results of attempts to weld overlapping sheets of nine aluminium and three magnesium alloys by the simultaneous application of heat and pressure at temperatures below their melting points. It was found possible to weld all the alloys to a greater or lesser degree, although in many cases large deformations are necessary. It is thought, however, that when the right method of surface preparation is found, the deformation required to obtain a weld may be very much lower than at present.

The best results were obtained with (*a*) an aluminium alloy containing magnesium and silicon in the proportions to give Mg_2Si ; (*b*) a duralumin type alloy, and (*c*) an aluminium alloy containing $1\frac{1}{4}\%$ manganese.

The technique may be associated with that of Powder Metallurgy in so far as what appears to be a welding or at least a strong adhesion takes place at room temperature, the adhesion being increased as the temperature rises. Great importance is attached to the effective cleaning of the surfaces, and this, together with the deformation necessary and the degree of pressure and heat required, seems to be analogous to methods used in Powder Metallurgy—so much so, that if the method can be applied to other metals besides the light

alloys, it may be practicable to combine the two methods and weld a metal powder projection to a solid metal part.

From a Production Research standpoint, the author has compiled an instructive and valuable report, exploring possibilities of manufacture in advance of general practice.

Issue of Journal to New Members.

Owing to the fact that output has to be adjusted to meet requirements, and in order to avoid carrying heavy stocks, it has been decided that the Journal will only be issued to new Members from the date they join the Institution.

Important.

In order that the Journal may be despatched on time, it is essential that copy should reach the Head Office of the Institution not later than 40 days prior to the date of issue, which is the first of each month.

APPLICATIONS FOR MEMBERSHIP AND TRANSFER RATIFIED BY COUNCIL ON 22nd MARCH, 1946.

As Members: J. R. Anderson, E. Bradshaw, T. R. Gupta, H. Lawetzky, W. J. Longworth, W. Ogilvie, C. G. Pettit, J. H. R. Ratcliff, E. B. Richardson.

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"TECHNICAL CONSIDERATIONS AFFECTING THE PRODUCTION & USE OF STEEL CASTINGS"

By A. B. LLOYD, A.M.I.P.E.

Presented to Wolverhampton Section, June 26th, 1945.

There is very little material published in this country on the subject of steel castings, which is written for the users of the product. This is not the case as far as the U.S.A. is concerned, for in that country there is a wealth of valuable data written for the special benefit of both designers and engineers using steel castings.

A short paper of this kind can only deal very briefly with the principal factors involved, and for those who desire more detailed information, I would refer them to *The Steel Castings Handbook*, published by the Steelfounders' Society of America, and to the *Cast Metals Handbook*, 1944, published by the American Foundrymen's Association.

The history of the first fifty years of the use of steel castings, commencing between 1860 and 1880, tells of an uphill struggle to evolve a product which consumers would consider to be consistently reliable. Steelfounders have not been assisted in their efforts by virtue of the fact that, until very recently, they have had to work largely to rule of thumb methods. They knew that certain techniques produced good results and others bad, but they did not know why. Consequently, progress has been achieved by a process of trial and error, and has been very much slower than would have been the case had there existed a solid background of scientific data on which to build.

The best that can be done within the scope of a short paper is to indicate the kind of information that the steelfounder requires from the user to enable him to give satisfactory service, and to give a brief description of manufacturing processes involved, together with an outline of the major technical problems which have to be dealt with.

To begin with, stress must be laid on the importance of a correct specification. The guiding principle here should be that the consumer should give quantitative information regarding his requirements, which will ensure that the castings are within his specification, and up to the required standard. The decision as to analysis, manufacturing technique and heat treatment should be left to the steelfounder, who should be prepared to furnish full details of the methods he proposes to adopt, if requested to do so.

The form in which the user's requirements should be specified is by a fully dimensioned drawing of the article as machined, specifying on the drawing the physical properties required of the material. The drawing should indicate where definite relationships between machined and black surfaces have to be maintained. Tolerances on both machined and black surfaces should be specified, and, where jigging points are known, it is highly desirable that these should be marked on the drawing.

Such information is valuable in working out details in connection with the manufacture of the pattern tackle, and is essential to the steelfounder's inspection organisation in enabling him to pass out castings as correct when complete. It is not a practicable proposition to mark out every casting fully before despatch, except in special cases, and reliance has to be placed on the checking of leading dimensions and clearances with the use of suitable templates, gauges, or jigs. If the user, therefore, indicates important dimensions on the drawing, these can be checked at the steelfounder's works, and subsequent hold-ups due to castings not fitting into jigs, etc., can be avoided.

Regarding material, the customer's specification should be such as will indicate to the steelfounder the nature of the service to which the castings will be subjected. This information, in most cases, can be limited to a statement of the physical properties required. It will comprise a statement of the results required from the tensile test or yield, ultimate stress, elongation, and reduction of area. Where the material is likely to be subjected to alternating stresses or shock, an Izod test, bend test, or fatigue test may be specified, as required.

Regarding analysis, it is desirable to state the maximum percentage of sulphur and phosphorus allowable, since these elements are universally harmful, except in steels where it is desirable to sacrifice strength for machinability. There may be cases where the presence of a particular element may be harmful in service on account of chemical action, and where this is the case, the fact should be stated.

The type of specification which is undesirable is that which attempts to specify to the steelfounder a complete analysis of the steel he is to use, together with full details of manufacturing procedure, heat treatment, and physical properties. Such a specification is quite valueless from both the steelfounder's and the user's point of view, since adherence to an analysis is not a guarantee of the physical properties of the resulting material.

The physical properties, which may be obtained from any given analysis, will depend on the melting technique, and on the heat treatment to which the castings are subjected.

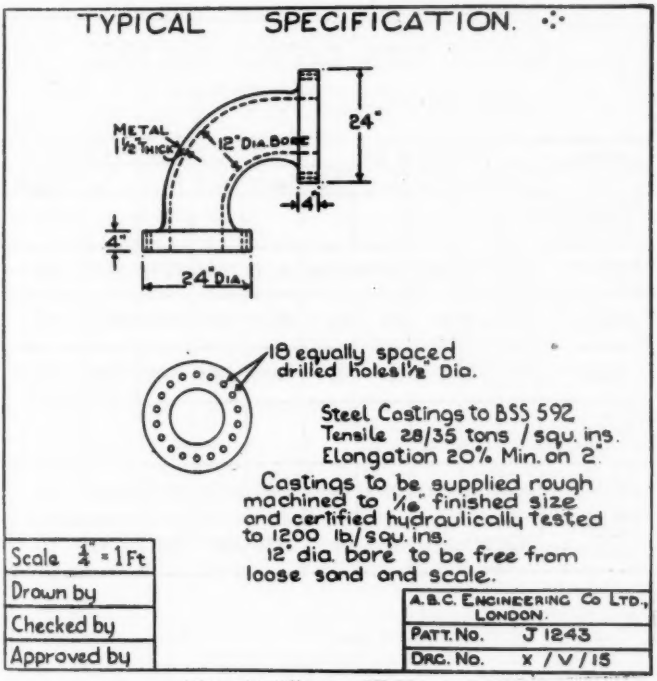
TYPICAL SPECIFICATION.
METAL 1½" THICK
12" DIA. BORE
24"
14"
¼"
24" DIA.
18 equally spaced drilled holes 1½" Dia.
Steel Castings to BSS 592
Tensile 28/35 tons / squ. ins.
Elongation 20% Min. on 2"
Castings to be supplied rough machined to 1/16" finished size and certified hydraulically tested to 1200 lb/squ. ins.
12" dia. bore to be free from loose sand and scale.
Scale ¼" = 1 Ft
Drawn by
Checked by
Approved by
A.B.C. ENGINEERING Co LTD., LONDON.
PATT. No. J 1243
DRG. No. X / V / 15

Fig. 1

In order to assist consumers of steel castings, a typical specification, as the writer thinks it ought to be, is given in Fig. 1.

The next step in the development of this subject is to consider the problem of applying the correct manufacturing technique, having received the drawing and specification.

Dealing first with the material side, it is proposed to give details of principal ranges of carbon and alloy steels which are suitable for the manufacture of steel castings. These may be classified in the following categories, and with each steel are given details of typical physical properties which may be expected.

Straight Carbon Steels.

Details of analyses and physical properties are shown in the upper half of Fig. 2.

STANDARD STEEL CASTING ANALYSES AND PHYSICAL PROPERTIES.

GRADE	ANALYSIS %					YLD.	UL.T.	ELONG.	R.of A.	IZOD.
	%C	%M	% Si	% S	% P	Tons/□"	Tons/□"	%on 2"	%	Ft./Lbs.
STRAIGHT CARBON STEELS										
SOFT	·2/·3	·6/·8	·35 APP.	·05 MAX.	·05 MAX.	14/18	26/35	25/30	35/45	20
MEDIUM	·3/·4	·6/·8	·35 "	·05 "	·05 "	18/24	35/42	18/25	25/30	15
HARD	·4/·5	·7/·9	·35 "	·05 "	·05 "	20/25	40/45	15/18	20/25	10
LOW ALLOY STEELS										
MEDIUM	·20/·26	1·2/1·6	·40 APP.	·04 MAX.	·04 MAX.	20/25	35/42	25/30	30/40	25
HARD-WEARING	·26/·33	1·2/1·6	·35 "	·04 "	·04 "	25/30	40/50	20/25	30/40	25

Fig. 2

These are typical analyses which will satisfy most normal engineering requirements where high ductility and high tensile stresses are not both required at the same time. Steels in the lower range of carbon content will give good ductility and moderate tensile stresses. Steels in the higher range of carbon content will give high tensile stress, but only at the expense of ductility. All these steels are heat treated by soaking at a temperature of 850°C. to 900°C., depending on the carbon content, the general principal being that the higher the carbon content the lower should be the soaking temperature.

Low Alloy Steels.

Details of analyses and physical properties are shown in the lower half of Fig. 2.

These steels are often described as "pearlitic manganese steels," and give a higher yield and ultimate stress than carbon steels, without corresponding reduction in ductility. They are generally heat treated by a normalising and tempering treatment. They can be quenched in water, oil, or air, according to the physical properties required and the thickness of the sections being treated. The lower range of carbon gives a material which has good machining properties, combined with high tensile stresses. The higher carbon range gives a material suitable for castings which are subjected to heavy wear, a typical example being Caterpillar Track Links.

Resort is necessary to high alloy steels in cases where the castings will be subjected to exceptionally exacting conditions in service. In nearly all cases, these are subjected to a complex heat treatment process, and, in this paper, an approximate indication only can be given of their analysis, heat treatment and physical properties.

The main categories which emerge are :—

(*a*) *Austenitic Manganese Steel.* This steel contains a maximum content of the order of 11 or 12% of manganese, the percentage of other elements being of the same order as those for carbon steels. Its physical properties are generally specified by the Brinell hardness number, which should be of the order of 200/250, and by the fact that it should give 180° bend test result. It has the disadvantage that it is almost unmachinable. Its chief advantage is that it is work-hardened in service, and little wear therefore results from hammering and abrasion. These steels are used for such castings as Crusher Jaws and Tramway Crossings.

(*b*) *High Carbon Chrome Steel.* This contains .7/.8% of carbon, approximately 1.5% of chrome, and approximately 1% of manganese. It can be hardened by quenching in air or oil, and tempered to give a minimum Brinell test result of 300. It is used for such castings as Mill Liner Plates. It cannot be used for very intricate castings because of a high tendency to crack as a result of mould resistance.

(*c*) *Rustless and Stainless Steels.* Two typical analyses are :—

(i) .15/.30% carbon, 13% chrome. This steel gives the following physical properties :—

Yield 20/25 ; Ult. 40/45 ; Elong. 25% ; Reduction of Area 35/45.

It can be oil hardened and tempered to give a Brinell test result in the range 183/207.

(ii) .20% carbon, 18% chrome, 8% nickel. This steel gives the following physical properties :—

Yield 15/17 ; Ult. 32/37 ; Elong. 25/45 ; Reduction of Area 25/45.

It can be air cooled or water quenched from 1150°C. to give a Brinell test result of 143/170.

(*d*) *Heat Resisting Steel.* A typical analysis contains .20% carbon, 10% nickel, .25% chrome, this steel being used for the manufacture of castings subjected to continual heating up and cooling in service, such as those used in heat treatment furnaces. Typical physical properties are :—

Yield 16/18 ; Ult. 34/38 ; Elong. 20/25 ; Reduction of Area 25/30 ; Brinell 156/174 ; Air cooled from 1050°C.

(*e*) *High Duty Steel.* Typical analyses are :—

(i) .26/33% carbon ; 1.2/1.6% manganese ; .30% molybdenum.

Yield 32/38 ; Ult. 45/50 ; Elong. 25 ; Reduction of Area 40 ; Izod 30.

The necessary physical properties are obtained by water quenching and tempering.

(ii) .4% carbon ; .6% manganese ; 2.5% nickel ; .6% chrome ; .4% molybdenum.

Yield 50/55 ; Ult. 58/65 ; Elong. 20 ; Reduction of Area 40 ; Izod 35/50.

These steels are very expensive to produce on account of the complications in both melting technique and heat treatment, and their use is only justified where exceptionally high physical properties are required.

(*f*) *Free-Machining Steel.* A typical analysis is :—

.28% carbon ; .90% manganese ; .09/.12% sulphur.

Physical properties to be obtained are :—

Yield 17 ; Ult. 32 ; Elong. 12 ; Izod 6/8.

As will be seen from the physical test results, this steel has inferior physical properties due to the high percentage of sulphur, and is brittle, after manufacture, in thin sections. It has the advantage that it can be machined at up to twice the speed of ordinary carbon steel.

Pattern Equipment.

The main factors affecting production of pattern equipment are the quantity required, the size and intricacy of the castings, and the dimensional tolerances specified.

Where the requirement from a pattern is limited to a few castings, it is obviously uneconomical to spend much money on pattern tackle. A loose wooden pattern and corebox are all that are necessary, and the rest is left to the skill and intelligence of the moulder.

Where large quantities are required from the pattern, it is bad economics to try and save money on the pattern, since the losses which will result from either defective or inaccurate castings, or from castings which are uneconomical to produce in terms of production time, are spread over a large volume of production. Where a large number of identical castings is required from the same pattern, resort, to a greater or lesser degree, to mechanisation is necessary in order to achieve economical production, and ensure that variations in dimensions and quality of the castings are reasonably limited.

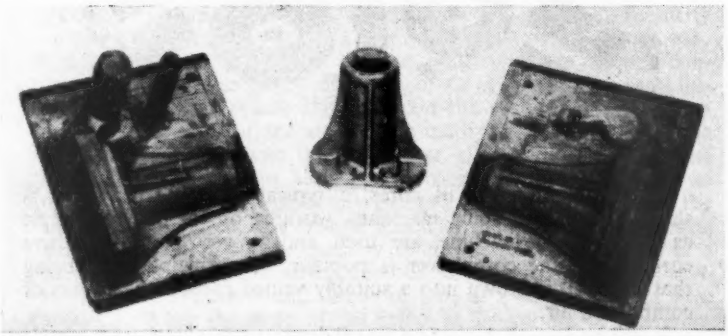

Fig. 3

Fig. 3 shows a Buffer Case casting beside the pattern tackle required for quantity production.

In manufacturing moulds, two main methods are in use for ramming sand into the moulding box in the minimum possible time. These are :—

(*a*) the moulding machine, which rams the sand into position over the pattern and in the moulding box by jarring the pattern mechanically ; and

(*b*) the sand slinger, which throws the sand mechanically over the pattern and into the moulding box, the pattern and the moulding box remaining stationary.

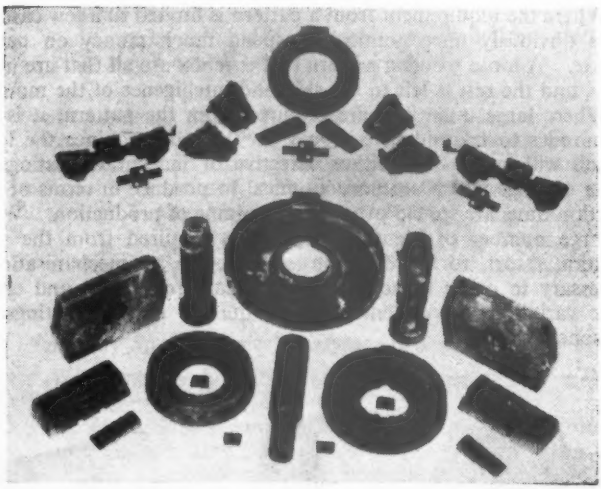

Fig. 4

In the manufacture of cores, a typical assembly of which is shown in Fig. 4, jarring machines, working on the same principle as the moulding machine, are used, and for very highly repetitive coremaking, the coreblower is popular, the principle here being that the sand is blown into a suitably vented corebox by means of compressed air.

It will be seen that in order to produce castings by these methods loose patterns and coreboxes are useless, and cheaply made pattern tackle will not stand up to the exacting conditions. Patterns and coreboxes must be made of hard wood, cast iron, or aluminium, according to the circumtsances, and mounted on plates to fit the machines on which the moulds or cores are to be manufactured.

It should also be noted that, due to various factors, which are dealt with later in the paper, substantial feeding heads have to be provided for in the manufacture of steel castings, and on repetitive jobs these feeding heads, together with the runner and ingates, become an integral part of the pattern tackle. In jobbing moulding, where small quantities are made on loose patterns, the shape

of feeding heads and the cutting of the runner and ingates is often left to the skill of the moulder. It will therefore be seen that the larger the quantities to be produced from any given pattern, the more work it is necessary to put into the pattern tackle, the extra cost being more than recovered in the lower cost of production which will result from producing the castings on a mass production basis.

Melting Technique.

Three main processes are used :—

1. The side blown converter process.
2. The open hearth process.
3. The electric furnace process.

Side Blown Converters.

These are fed with liquid iron containing over 2·5% carbon and 1% silicon which is produced by melting a mixture of approximately 25% of steel scrap and 75% of pig iron in a coke-fired cupola. The metal from the cupola is tapped into a desulphurizing ladle, where the greater part of any sulphur, which may be in the iron as an impurity or picked up from the coke, is removed by contact with soda ash. The steel is then tipped from the desulphurizing ladle into the converter, where it is subjected to a blast of air at approximately 2½ lbs. pressure per square inch impinging on the surface of the molten metal. The effect of the air blast is oxidizing, the oxygen in the air blast combining with the manganese, silicon and carbon in the molten iron, giving out heat in the process. The carbon content of the iron is then progressively reduced ; the temperature, at the same time, is raised, and after a period of the order of 20 minutes, varying according to the capacity of the converter, the iron, at a temperature of approximately 1300°C., is converted into steel containing .1% of carbon and silicon or less, at a temperature of over 1600°C. When the drop of the flame, at the mouth of converter, indicates that the carbon content is at a minimum, the blast is shut off, and finals, in the form of deoxidizers such as ferro-manganese and aluminium and alloying materials where these are required, are added to give a steel of the required specification.

The Open Hearth Process.

This consists of melting a mixture of scrap steel and pig iron on a hearth in a refractory chamber, the heat being provided by the introduction of air and producer gas through separate ports. The combustion of the producer gas takes place in the furnace chamber containing the charge. Waste gases are exhausted through ports on the opposite side of the chamber to the inlet ports, and

passed through regenerating chambers consisting of a latticework of heat-resisting bricks. There are two sets of these chambers under the furnace, and they are so arranged that the flow of gases through the furnace can be reversed, the regenerators, heated by the exhaust gases, being used to heat the inlet gases immediately after reversing the flow.

This process has its chief application where large quantities of steel are required for casting ingots, and its use as a means of melting for steel castings appears to be dying out in favour of the large sizes of electric arc furnaces.

Electric Furnaces.

There are two main types, namely, the induction furnace where the charge is surrounded, in principle, by electric coils carrying a heavy and constantly reversing current, thus using the magnetic properties of the steel charge to heat it ; and the electric arc furnace where the scrap is heated by a carbon arc struck between carbon conductors and the charge itself.

The latter process is found to produce steel of the highest quality, and is becoming increasingly popular for the melting of steel for steel castings. A basic lining is generally used, lining materials consisting either of rammed dolomite or magnesite bricks. The electric arc furnace uses an all-steel scrap charge, and is not dependent for fuel on the oxidization of impurities, as in the converter process, nor in the burning of gas, as in the open hearth process.

In both the open hearth and converter processes, the final refining of the steel has to take place in an oxidizing atmosphere, which means that there is always a danger of the steel being oxidized when poured into the moulds.

In the basic arc process, by the control of slag composition, oxidizing, or reducing conditions can be obtained at will. The usual procedure is to melt down the scrap charge under oxidizing conditions, inducing a vigorous boil to eliminate dissolved gases produced by rust on the scrap and non-metallic inclusions within it. This procedure promotes fluidity. After boiling for the specified time, the oxide remaining in the steel is reduced by replacing the oxidizing slag by a mixture of limestone, fluorspar, and anthracite coal, a characteristic of this slag being the formation of calcium carbide and its falling to powder on exposure to the atmosphere.

Steel having low impurities is made by this process, phosphorus being removed by oxidizing conditions, and sulphur by reducing conditions.

Electric arc furnace melting has the very great advantage of extreme reliability, and it has been proved beyond question that

steel can be obtained from it of a purity which is not reached by either converter or open hearth processes.

Sand Practice.

It is now proposed to break off from the melting of metal, and examine the type of materials which are required for the manufacture of moulds suitable for casting steel. The problem is a more complex one than is the case with cast iron and non-ferrous foundries, owing to the high temperature of liquid steel.

In order that the steel may be sufficiently fluid, it has to be poured at a temperature of between 1600 and 1700°C., and there are very few refractories known which will stand up to these temperatures. The only refractory material which is in adequate supply is silica sand, occurring either in the pure state or in the form of naturally bonded sand, where it is combined with clays which are sufficiently refractory to withstand the temperature of molten steel. Very few clays have a melting point sufficiently high to enable them to maintain their shape in a mould when in contact with molten steel.

Moulding practice falls into two main categories, namely, (*a*) green sand moulding, and (*b*) dry sand moulding.

Green Sand Practice.

In green sand moulding, the moulds are not passed through a drying stove between moulding and casting, and some provision therefore has to be made for the moisture in the sand to escape from the outside surface of the mould when the molten steel enters it. This is achieved by making the moulds of a sufficiently coarse grained sand, so that the sand, when rammed hard against the pattern, is sufficiently porous to enable steam generated to escape through it without disturbing the mould surface in contact with the metal. It is generally found that the sand needs to be more moist when actually moulded than it is when the mould is cast, owing to the fact that moisture evaporates and the mould dries out at room temperature. Although moulding sand, mixed with clay, will retain its shape while moist, when dried it tends to become friable, and the sand near the surface will be washed away into any stream of molten metal impinging upon it. To counteract this, it is necessary to add an organic binder, which will ensure that the mould surface hardens as moisture evaporates. The main constituents, therefore, for green sand practice are :—

(i) Reasonably coarse grained silica sand.

(ii) A refractory bonding clay. This is already present in the raw material in the case of naturally bonded sands ; in synthetic sand practice, naturally occurring pure clays are added.

(iii) An organic binder, such as dextrine, which hardens off the surface of the mould as it dries out.

Dry Sand Practice.

It is found that in the manufacture of heavy castings, or castings of exceptionally thick sections, satisfactory results are not obtained from green sand practice, and it is thus necessary to dry the mould out completely by heating in a stove to a temperature of between 200 and 300°C. In this case, two main constituents are necessary :—

(i) A refractory material which will again be silica sand, but in this case it must be a finer grain and of a more compact nature when rammed than is the case in green sand practice.

(ii) A clay which will enable the sand to maintain its shape during handling between moulding and drying, and develop adequate strength when dried.

Coremaking.

Cores are almost universally dried after manufacture, although there are individual cases where it has been found advantageous to use green sand cores. For cores adjacent to thin sections of metal, a coarse silica sand is generally used, together with linseed oil to act as a bonding agent. Linseed oil, when heated to 300 to 400°C., undergoes a chemical change, forming a compound which will bind the grains of silica sand together into a cohesive mass. The smallest possible quantity of green bonding clay is incorporated, only so much being used as is necessary to prevent the core sagging between the time it is moulded and the time it is dried. For heavier cores, and those which are in contact with thicker sections of metal, more finely grained silica sand is necessary, and a higher proportion of green bonding clay will be used, since the difficulty of preventing the core from sagging increases with its size.

Summary of Foundry Processes.

A general description has been made of the materials which are necessary in the manufacture of a steel casting, and some reference has been made to the tackle required for the manufacture of moulds and cores of different types. Metal is brought from the furnace to the foundry by means of a steel ladle, lined with refractory material, and the metal is poured into the mould either by teeming over the lip of the ladle, or teeming through a firebrick nozzle in the bottom.

Illustrations 5 to 7 show the various stages in the assembly of a mould, followed by the processes of casting and knocking-out.

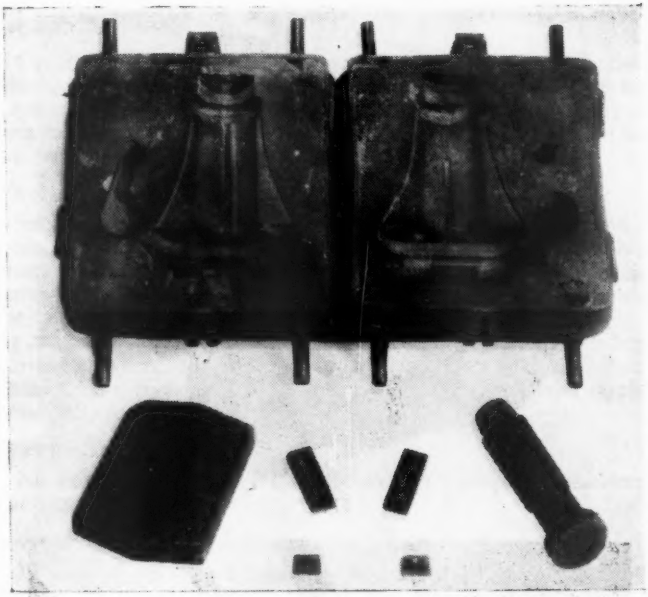

Fig. 5

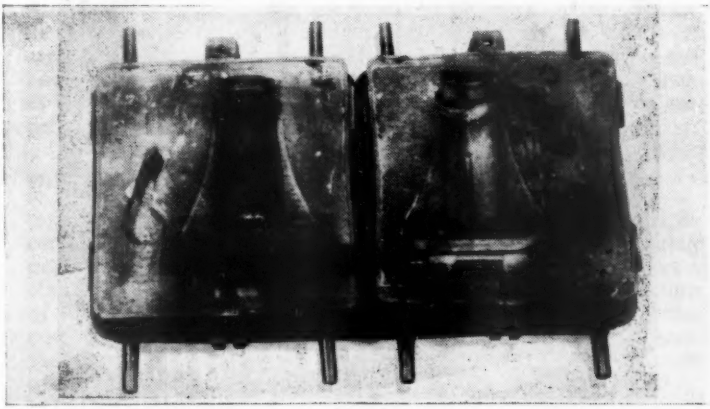

Fig. 6

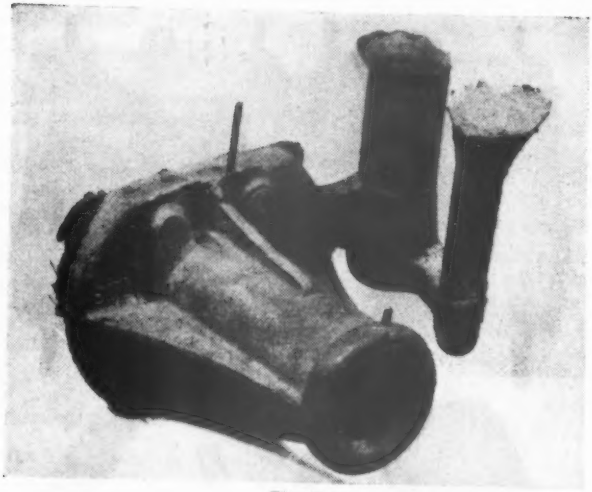

Fig. 7

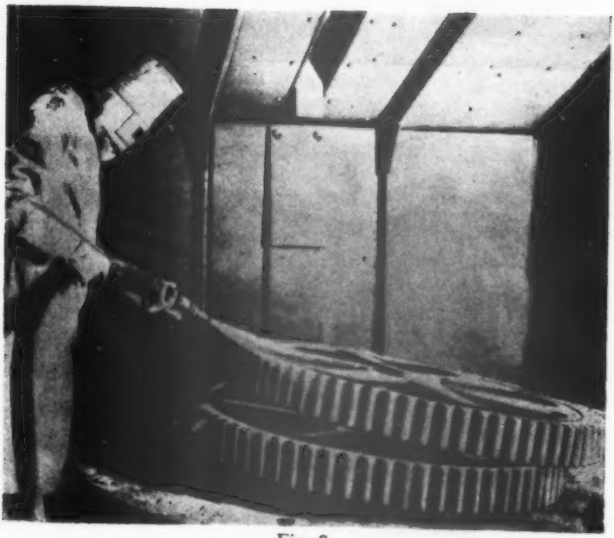

Fig. 8

Fettling Processes.

Castings are separated from the sand on the foundry knock-out, which, in repetitive foundries, will consist of a vibrating grid with a subterranean conveyor to return sand for re-milling. They are then transferred to the fettling shop, where the fettling processes are carried out.

Shotblasting.

Small castings are shotblasted, to remove all adhering sand, in a wheelabrator cabinet which consists essentially of a revolving drum into which is sprayed a continuous stream of steel shot. Larger castings are sprayed with steel shot by an operator who enters the cabinet wearing suitable protective clothing, as shown in Fig. 8. As can be imagined, this is a dusty process, and a technique is being developed where this adhering sand is removed by high pressure water. This Hydro-Blast, as it is called, is so far being applied principally to heavy castings.

Dressing.

All fins and flashes are removed in this process by pneumatic hammers.

Removal of Heads and Runners.

In view of the special nature of steel, nearly twice as much steel has to be poured into the mould as is finally contained in the finished casting, surplus metal being contained in feeding heads. These heads are removed by oxy-acetylene, or oxy-propane cutting. After oxy-acetylene cutting, the places on the castings from which the heads have been removed, are ground smooth by means of carborundum grinding wheels. Either at this stage, or after the burning operation, the castings should be inspected for defects such as sand inclusions, seriously defective castings being thrown out before further work is done upon them.

Heat Treatment.

Castings, as received from the foundry, are in a somewhat brittle condition and are in a quite unsuitable state for most engineering processes. The structure is coarse grained, and the material is in a state of considerable internal stress due to the natural contraction of the steel having been resisted by the mould and by differential cooling as between one part of the casting and another. In all cases, therefore, an annealing process is necessary to refine the structure and relieve internal stresses.

In the case of carbon steels, heating to a temperature of approximately 850°C., and holding it at that temperature for several hours,

will give the steel suitable mechanical properties. In the case of alloy steels, each alloy has its own peculiar heat treatment process. For example, nickel, chrome, and molybdenum steels require to be normalised and cooled in air at approximately 950°C. They are then subsequently heated to a lower temperature—approximately 800°C.—quenched in oil or water, and tempered at approximately 650°C. Steels containing 13% manganese are taken up to approximately 800°C. and quenched outright in water.

The purposes of these treatments and the changes in structure of the material which they bring about are, for the most part, specified in standard metallurgical text books, and this aspect of the subject does not come within the scope of this paper.

Final Processes.

After heat treatment the castings are finally processed by further chipping and shotblasting to remove scale, and they are then subjected to a close inspection for material and dimensional defects before despatch.

Inspection.

An adequate inspection routine is absolutely essential to enable steel castings to meet modern engineering requirements.

Due to the high melting point of steel, and the comparatively small difference between the melting point of steel and the refractories used to contain it in the mould, a certain percentage of scrap is to be expected apart from that which is directly attributable to bad workmanship. Although certain defects are only revealed on machining, these are in a minority, and by a searching final inspection of the rough castings, all but a very small percentage of defective castings can be segregated and scrapped before being delivered to the consumer.

In the case of castings where unrevealed defects may cause loss of life due to failure in service, resort can be made to the use of X-rays, Gamma-rays, and other methods of non-destructive testing. A typical example of where this technique is applied is in connection with aircraft castings.

For ordinary commercial work, however, the cost of such a procedure is prohibitive and hardly justified.

Defects.

So much for the manufacturing processes. It now remains to discuss some of the defects to which steel castings are subject, together with the measures which are taken to overcome them.

Sand Inclusions.

These are sometimes revealed on machining as shown in the casting illustrated in Fig. 9. Generally, however, castings containing sand inclusions can be detected on inspection, since it is rarely that a patch of included sand does not break through to the surface of the casting. Where it does, the surface is broken, and the sand inclusions can easily be detected by a trained observer.

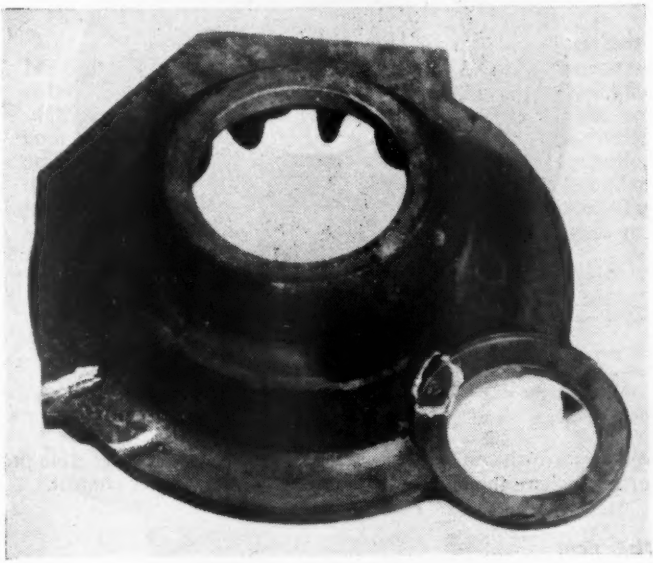

Fig. 9

Blow Holes.

Any cavity revealed on machining is apt to be described as a blow hole. To the producer of steel castings, however, the term "blow hole" is confined to small cavities which are the result of gases, dissolved in the steel, coming out of solution on solidification. This can be caused by insufficient deoxidization of steel in the furnace, or by insufficient drying and venting of the mould. A typical example is shown in Fig. 10.

This type of defect was not uncommon in steel castings produced in the early days of the industry when the technique of deoxidizing was not properly developed. The proper use of deoxidizing materials,

Fig. 10

such as ferro-silicon, etc. has reduced this defect to negligible proportions where the melting technique is under proper control.

Distortion.

It is common experience in the manufacture of patterns and tackle for quantity production of steel castings that sample castings must always be made before bulk production is proceeded with. A bar of steel 1 foot long, allowed to contract unhindered from its solidifying point to room temperature would contract by approximately $^{1}/_{38}$ foot. If this contraction is resisted, it may vary from no contraction at all to 1 in 38, according to the amount of resistance offered by the mould. The average figure for contraction, used by patternmakers, is 1 in 60. When, therefore, a casting of any complexity is manufactured, the contractions which take place have to be found out by experience, and the pattern tackle corrected to the actual contractions after the production of sample castings. On large steel castings, it will be found that considerable variations may take place in the dimensions of individual castings manu-

factured by the same process and in the same foundry. This factor makes it necessary to provide for liberal machining allowances on large castings to cater for this peculiarity. Bending of the casting may also result due to differential stresses set up by varying resistance to contraction in different parts of the same casting.

Cracks.

There are three main types: (*a*) hot tears; (*b*) cold cracks, or "clinks"; and (*c*) quench cracks.

(*a*) *Hot Tears.* Mention has been made of the fact that steel has a large co-efficient of linear contraction, and that resistance to contraction is set up by the cores in a mould during the solidification of the steel. A hot tear results when resistance of the core to contraction stresses the steel beyond its breaking limit, while it is still plastic, at a high temperature. Such cracks are very noticeable, and, in extreme cases, can be as much as $\frac{1}{4}''$ wide. The edges are jagged and the fracture is always dull in appearance. Fig. 11 shows a Bomb Body casting containing this defect in a marked degree.

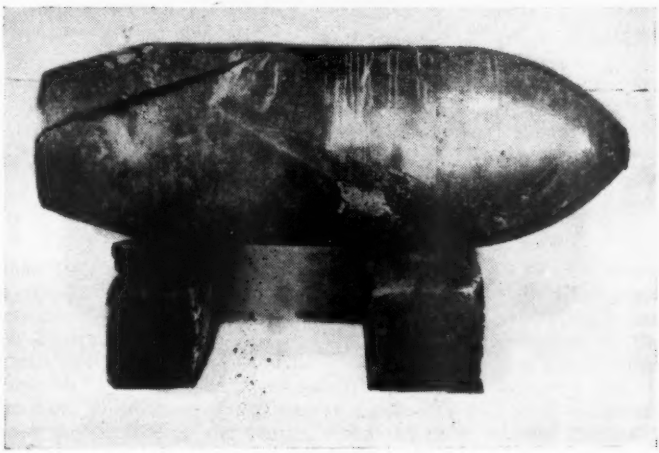

Fig. 11

(*b*) *Cold Cracks or "Clinks."* Steel in the as-cast condition has a coarse grain structure, and is extremely brittle. Due to mould resistance and different rates of cooling of thick and thin sections, and other causes, the casting is at the same time in a

highly stressed condition. If the stresses are not relieved by an annealing process, the steel of which the casting is made is likely to be stressed during cooling off to the breaking limit, and a sharp fracture, going right across the section of the casting, results when the casting is cold, particularly when a heavy boss and a heavy rim are joined by arms of a thin section. This defect may be overcome by splitting the boss.

(*c*) *Quench Cracks.* These may be induced during the removal of heads on high carbon or alloy steels. They result from high local stresses induced by sharp changes of temperature from either burning-off with oxy-acetylene, or over-drastic quenching. They are not generally deep-seated, and only penetrate a small proportion of the section of the casting. They may, however, occur so extensively over the surface of the casting as to make their repair uneconomical. Such a crack is shown at "A" on Fig. 12 and "B" on Fig. 13.

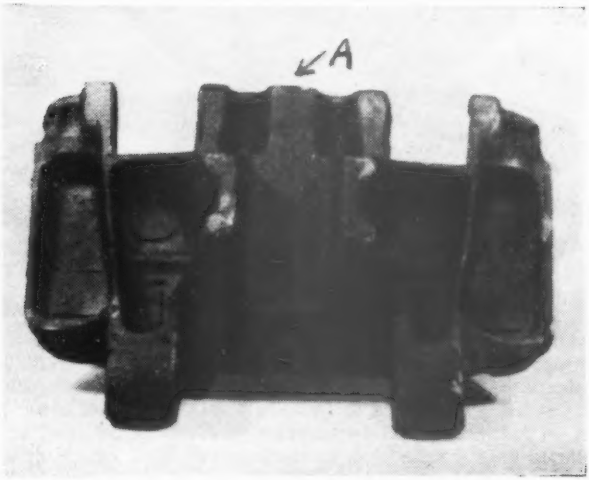

Fig. 12

Cavitation.

This defect has been left till last because it introduces us to a property of steel which presents serious problems in the production of steel castings. The contraction has been mentioned which

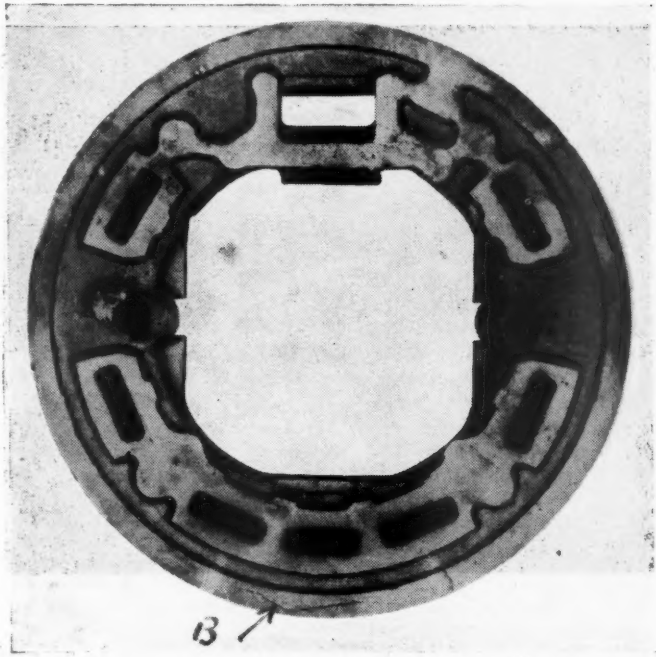

Fig. 13

takes place between solidification of the steel and its cooling down to room temperature. Another type of contraction takes place between the melting and solidifying of the steel at its melting point, the contraction amounting to about 5% of the volume of the liquid steel. One cubic foot of liquid steel weighs 437 lbs.; one cubic foot of solid steel, at its solidifying point, weighs 490 lbs. It therefore follows that if we imagine a cube of liquid steel to solidify from the outside to the centre, when the cube is solid there will be a cavity in the middle. This process takes place in sections of steel castings of any thickness, unless measures are taken to force the liquid metal into the cavities until the metal is completely solid.

Liquid metal is fed into potential cavities in the section of the casting by means of feeding heads, which are so arranged that the force of gravity, combined with atmospheric pressure, should force the liquid into the cavities. Until comparatively recently,

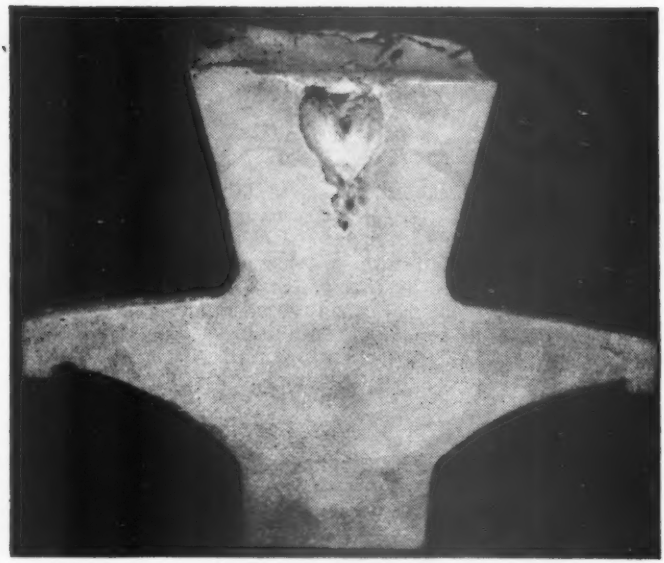

Fig. 14

gravity heads, placed on top of the casting, were chiefly adopted. Fig. 14 shows a typical instance of this method. Other methods now in use are :—

(i) The "whirlgate head" which is connected near the bottom of the casting in such a way that the casting solidifies before the head, and liquid metal is fed by atmospheric pressure into the casting.

(ii) The "atmospheric head," which can be connected either at the top or near the bottom of the casting, where a core is used to ensure a connection between the inside of the head and the atmosphere. By this means, considerable economy of head metal is effected by comparison with the "whirlgate" head.

(iii) Centrifugal force, obtained by spinning the mould in the centrifugal casting process.

Of these methods, special mention needs to be made of the atmospheric pressure method of feeding castings, this consisting of inserting a round sand core which is permeable to air, and has

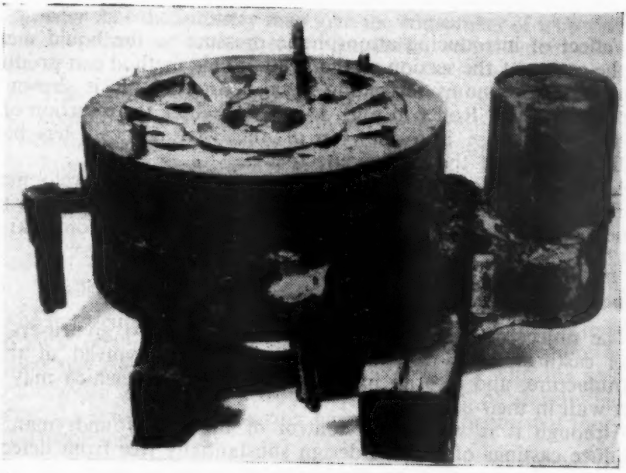

Fig. 15

Fig. 16

the effect of introducing atmospheric pressure to the liquid metal in the centre of the section of the head. This method can produce considerable economy in feeding metal. An example is shown in the Cement Mill Roller in Figs. 15 and 16, where the insertion of a small round core into the top of the feeding head has been sufficient to feed the casting effectively.

A full description of the research that has led to the development of the use of this type of head is contained in a paper given to the American Foundrymen's Association by Taylor and Rominski in 1942.

Conclusion.

The object of presenting this paper has been to give users of steel castings some insight into the problems involved in their manufacture, and also an indication of the defects which may be met with in their use.

Although it is within the control of the steel foundryman to produce castings of a given design substantially free from defects, it is often the case that, by minor modifications of design, the steel foundryman's problem in producing sound and serviceable castings is made more straightforward and less costly, with consequent benefit to the user.

It has not been possible, within the time available, to cover the question of design of steel castings in this paper, but some useful data is available in the publications of the American Foundrymen's Association, referred to earlier in the paper. Work is also in progress in this country on compiling similar information.

As the writer has attempted to cover the whole field of steel casting production, the survey has, of necessity, been sketchy. If there is any subject which has been touched upon which merits further study, reference has as far as possible been made to sources of more detailed information.

Lastly, one word on the future of the steel casting industry. We often hear that in the future steel castings will be dispensed with in favour of fabricated assemblies, castings in light alloys and high duty alloys, and even by plastics. No doubt there are many cases where one or other of these materials and methods of manufacture has been found to give more satisfactory service than steel castings. Where it can be proved that one or other of these methods produces a more economical and serviceable product than the steel foundry can, there is no argument but that the alternative form of manufacture should prevail.

There is no doubt, however, in the mind of the writer that in the future there will be an expanding market for the products of the steel foundry industry, particularly in the alloy field.

In order that the industry may give the consumers of its products the service they are entitled to expect, there are two main requirements :—

1. That individual producers in the steel foundry industry continue to develop the quality of their product in accordance with the best known techniques, and maintain within their foundries a high standard of inspection.
2. That consumers of steel castings take the producers into their confidence, giving them a chance to make known their manufacturing problems, in connection with particular designs and specifications, before the design or specification is finalised.

The first requirement stated above is entirely up to the producers, and most of them are fully alive to the issue. They do, however, require the assistance of consumers in connection with the second requirement, and judging from his experience of developments during the war period, the writer has every confidence that this will be forthcoming.

Research Department: Production Engineering Abstracts

(Prepared by the Research Department.)

NOTE.—*The Addresses of the publications referred to in these Abstracts may be obtained on application to the Research Department, Loughborough College, Loughborough. Readers applying for information regarding any abstract should give full particulars printed at the head of that abstract including the name and date of the periodical.*

HEAT TREATMENT.

The Isothermal Heat-Treatment of Steel, by E. F. Watson and J. McArthur. (*Machinery, 28th February,* 1946, *Vol.* 68, *No.* 1742, *p.* 265, 8 *figs.*)

During the hardening of steel an internal structural change occurs which is accompanied by a change in volume. Isothermal treatment has shown that within certain ranges, enhanced physical properties can be expected without allowing this critical change to occur. The most important part of the cooling curve is that from hardening temperature to approximately 450°C. If this temperature can be reached throughout the section within the critical time, then the subsequent cooling can be varied in accordance with the final properties required. Isothermal treatments make use of the slowing-up in the critical rate below 450°C. If the material is held at suitable temperatures below this point and down to about 250°C., a range of properties can be obtained in some ways similar to that now available by varying the tempering temperature after a continuous quench for lower final hardness. The reason for the enhanced properties is probably the elimination of the state of internal stress achieved by avoiding the austenite-martensite transformation. As a result, distortion is reduced to a minimum if not eliminated. This method, which avoids the passage through the lower critical point, is generally referred to as "austempering." If a martensitic structure is desired, the isothermal method quenches rapidly to 250°C. and holds this temperature until it has been established throughout all the sections of the work while the high-temperature structure is retained. The part is then withdrawn and cooled relatively slowly in air, so that the mass transforms uniformly into martensite. By this means the non-uniform strains are avoided and also the martensite so formed is more ductile than can be obtained by continuous cooling. The process is completed by the appropriate temper if desired and is called "martempering." Other advantages of isothermal treatment are indicated. Isothermal methods termed "cyclic annealing" give excellent control over final structure. The properties of molten salt for quenching are discussed at length. Practical results are described for a number of items, and the advantages of this type of treatment are summarised as follows: finished machine parts can be treated, distortion and quench cracks are reduced, scale and decarburizing are eliminated and toughness and ductility are increased.

High Frequency Heating, by James F. Driver. (*Machinery Lloyd, 23rd February,* 1946, *Vol. XVIII, No. 4A, p.* 49, 6 *figs.*)

High frequency heating falls into two main divisions, Eddy current or Induction heating, which is applied to metallic conductors, and Dielectric heating used for non-conductors, such as plastics, glues, wood porcelain and cotton goods. The principles of both types are explained, and examples of their use are given.

Larger Induction Heating Coils Meet Small-Lot Requirements, by G. V. Bates. (*The Machinist*, 16*th March*, 1946, *Vol.* 89, *No.* 49, *p.* 2531, 8 *figs.*)

Six work coils of basic design enable the jobbing shop to handle a wide variety of brazing and heat-treating work of improved quality, on a sound cost basis.

Handling Equipment for Heat-treatment Furnaces, by H. D. Hendrick. (*Machinery*, 21*st March*, 1946, *Vol.* 68, *No.* 1745, *p.* 367, 5 *figs.*)

The design of chain and slat conveyors, pusher-type furnaces and quenching gear for batch and continuous operation is dealt with.

EMPLOYEES, APPRENTICES.

Engineering Apprenticeships in Medium-sized and Small Companies. (*Production and Engineering Bulletin, February*, 1946, *Vol.* 4, *No.* 37, *p.* 467, 1 *fig.*)

Large firms are better placed in securing satisfactory recruitment and training for their future supply of skilled man-power, but the medium-sized and small firms are of special importance to British industry. A scheme is described which comprises an initiation period, trade selection, planned progressive training, close supervision of progress and parallel technical education. A senior executive should be made responsible for the control of training, education, and welfare of entrants to the firm. Boys from all types of school are included. A suggested form of record card is given.

FOUNDRY.

Application of Time Study to Rate Fixing, by H. S. Ward. (*Foundry Trade Journal*, 31*st January*, 1946.)

This was originally a paper given by the author to the Institute of British Foundrymen. It deals briefly with forms on which information can be recorded, the use of stop watches, period over which a study should be extended, the make-up of the time-study observer, and other relevant points. The examples of work quoted were drawn from foundry practice.

(*Communicated by Machine Shop Magazine.*)

GEARING.

The Suppression of Noise in Gears, by A. B. White. (*Power Transmission*, 15*th March*, 1946, *Vol.* 15, *No.* 170, *p.* 276.)

Part 1. The four main types of gear noise are caused by defective tooth spacing or badly formed tooth profiles, eccentricity, rough tooth surfaces and the engagement note of the gears which is dependent upon the pitch and speed of the engaging gears. The first three are determined by accuracy and workmanship. The real solution of the problem seems to be more in elimination of the various sources of noise rather than in the damping of existing sounds, and the various factors are discussed, including resonance, separation of the tooth surfaces under load, variations in tooth loading, changes from rolling to sliding motion on the tooth profiles, and variations in motion resulting from torsional or bending deflections in the pinion or gear.

The Fallacy of the Multi-Start Hob for Spur and Helical Gears, by N. Waterworth. (*The Machinist*, 9*th March*, 1946, *Vol.* 89, *No.* 48, *p.* 2481.)

In cutting helical gears the multi-start hob is advantageous only if it is necessary to set the axis of the hob nearly perpendicular to the axis of the work in order to minimize run-out clearance. In the case of spur gears or helical gears of low helix-angle, the multi-start hob has no advantage whatever.

Revised Gear-Blank Tolerances Cut Costs, by K. E. Bauerle. (*The Machinist, 9th March*, 1946, *Vol.* 89, *No.* 48, *p.* 2500, 5 *figs.*)

Revised gear-blank machining tolerances, sound design and proper evaluation of the required quality have helped to put instrument-gear manufacture on efficient basis.

JIGS AND FIXTURES.

Indexing Fixture Facilitates Production of Large Machine Tool Castings, by G. C. Gilbert. (*The Machinist, 16th March*, 1946, *Vol.* 89, *No.* 49, *p.* 2571, 7 *figs.*)

All major milling operations are completed at one setting and alignment and correct angular relations of surfaces are assured.

MACHINE ELEMENTS.

Overload Clutches, by R. Waring Brown. (*Power Transmission, 15th March*, 1946, *Vol.* 15, *No.* 170, *p.* 271, 6 *figs.*)

A consideration of some developments in the design and construction of automatic overload release.

MACHINING, MACHINE TOOLS.

Modern Machine Tool Practice, by T. P. N. Burness. (*Transactions of the Institution of Engineers and Shipbuilders in Scotland, February*, 1946, *Vol.* 89, *Part* 4, *p.* 245, 15 *figs.*)

Modern production methods are illustrated by the manufacture of vertical milling machines. The manner in which a design is presented by the drawing office to the works is of vital importance, and recommendations are given, covering standardisation in drawings and specification of finish and limits. Castings should be designed for machine moulding and must go into their respective fixtures without difficulty ; jigs and fixtures should be used for producing and setting interchangeable cores. Metallurgical control is essential for the foundry and heat treatment department. The efficient planning of a job for manufacture is the most important link in the organisation. The personnel should include men who have had extensive experience of machining and fitting. For machine tool work adequate machining times must be given and accuracy must have precedence over time. Simplicity and maintenace of jigs, tools and fixtures is essential. If 50 machines of a particular design are to be manufactured, even spread over a period, it will pay the manufacturer handsomely to utilize jigs, tools and fixtures for the main components, and as the number increases, the machine can eventually be tooled up. It is essential to have 100 per cent. inspection. The department should be entirely independent of the general works organisation, but must not relieve the works' executives from responsibility for defective work. The erection time cycle of this machine was 18 hours.

Facilitating Speed Control for Modern Lathes, by C. C. Downie. (*Power Transmission, February*, 1946, *Vol.* 15, *No.* 169, *p.* 174.)

Electric braking and speed variation, either stepless or in fixed ratios, are now common. Their usefulness has been enhanced by push button and pre-selective control. The different A.C. and D.C. methods are briefly described. Feed drives may also be operated by separate electrical means.

Speed and Precision in Turning Motor End Shields. (*The Machinist*, 23*rd February*, 1946, *Vol.* 89, *No.* 46, *p.* 2407, 4 *figs.*)

Production of end shields for fractional horsepower motors was cut from 7 min. to 50 sec.

Precision Boring for Obtaining Concentricity. (*Machinery*, 28*th February*, 1946, *Vol.* 68, *No.* 1742, *p.* 273, 10 *figs.*)

This method can produce holes round and concentric within 0·0001 inch total indicator reading. Examples of work and accuracy obtained are given.

Modern Milling Practice. (*Aircraft Production*, *March*, 1946, *Vol. VIII*, *No.* 89, *p.* 125, 3 *figs.*)

A summary of American cutter, feed and speed, and cutter-grinding data is given. Factors affecting carbide cutters, the importance of chip thickness, and some theories on negative rake cutting are explained. The procedure for speed and feed selection with the aid of tabulated values is outlined.

Drilling, Reaming and Facing Zinc-alloy Diecastings. (*Machinery*, 28*th February*, 1946, *Vol.* 68, *No.* 1742, *p.* 285, 4 *figs.*)

For drilling a standard point angle of 118 deg. is generally used. This may be increased or decreased for special reasons. A narrow flat face is sometimes ground along the cutting edge to give zero rake. At least a 12 deg. lip clearance is needed. The chisel edge angle is usually from 120 to 135 deg. The use of carbide-tipped drills is warranted only in long-run production. High-speeds of 200 to 300 peripheral feet per minute and slow feeds give the best results. Standard machine reamers yield good results if the width of the land is reduced. For holes having a cast-in keyway, spiral flutes are essential. The flutes should be deep and polished. Reamers should normally be made with a zero rake and the clearance angle at the back of the land may vary from 10 to 30 deg. Carbide tips can be employed to advantage on long-run work. Reaming and facing by the use of combination tools such as that shown is very common.

CHIPLESS MACHINING.

The Effect of Material in Deep Drawing Operations. (*Machine Shop Magazine*, *March*, 1946, *Vol.* 7, *No.* 3, *p.* 49, 4 *figs.*)

The production of deep drawn components is one of the worst of press operations and choice of material will influence results. A material for deep drawing should be such as to give a good surface finish after drawing, be ductile to withstand cold working, and have sufficient tensile strength to withstand the stress of deep drawing. These factors are discussed in relation to actual jobs, as well as generally in relation to brass and steel.

Practical Problems of Light Presswork Production, by J. A. Grainger. (*Sheet Metal Industries*, *March*, 1946, *Vol.* 23, *No.* 227, *p.* 497, 12 *figs.*)

Shallow drawn work is described in this instalment.

Forging Aluminium Pistons on Mechanical Presses. (*Machinery*, 21*st March*, 1946, *Vol.* 68, *No.* 1745, *p.* 361, 4 *figs.*)

The billets are formed into a truncated cone shape, rough blocked, finish blocked and closed. The stages of the process, and certain of the tools, are illustrated.

Aluminium-Alloy Strain Distributed at Elevated Temperatures, by George Sachs, George Espey and W. F. Brown. (*The Machinist, 2nd March,* 1946, *Vol.* 89, *No.* 47, *p.* 2464, 3 *figs.*)

Part II. Geometry of die, location of friction, and alloy condition are variables which determine results of hot-die stretching and are discussed.

MANUFACTURING METHODS.

Tooling New Contracts, by L. Maguire. (*Machinery Lloyd, 2nd March,* 1946, *Vol. XVIII, No. 5, p.* 67.)

Suggestions for: (1) The method of design, manufacture and purchase of the necessary jigs, tools and equipment, (2) the major reasons for the use of jigs, tools and machine tools, and (3) the economic factors governing the design and manufacture of jigs and fixtures, are given. It is stressed that necessary factors for success are: a firm advertising and sales policy with manufacturing quantities laid down, and that the planning department require: a detailed knowledge of their firm, a sound grasp of the duties relating to their own particular functions, and an economic sense.

Subcontract Seafire. (*Aircraft Production, March,* 1946, *Vol. VIII, No.* 89, *p.* 138, 23 *figs.*)

The chief interest of this article lies in the methods whereby groups of operatives working on time balance stages move from one fixture to another to complete their stages on different assemblies, thus avoiding an elaborate line assembly system. In planning assembly procedure, graphs have been used to a very large extent.

Rolls-Royce Griffon 65, Part II, by J. A. Oates. (*Aircraft Production, March,* 1946, *Vol. VIII, No.* 89, *p.* 115, 26 *figs.*)

Machining operations on some major light-alloy components, including the crankcase, cylinder head, reduction gearcase and supercharger casing are described.

Pump Production by Tool-room Precision Methods. (*Machinery,* 21*st February,* 1946, *Vol.* 68, *No.* 1741, *p.* 233, 13 *figs.*)

Lapping is used to a great extent for shafts, plates and gears. Gear teeth are shaved and burnished and checked on the Fellows Red Liner. The gauges and gauge-blocks are all checked on the Federal electronic gauge, and Electrolimit and Air-O-Limit gauges are used extensively throughout the shop.

MATERIALS, MATERIAL TESTING.

Light Metals—A Critical Review, by S. A. J. Sage. (*Mechanical World, February* 22*nd,* 1946, *March* 1*st,* 8*th,* 15*th,* 1946, *Vol.* 119, *Nos.* 3086, 3087, 3088, 3089, *pp.* 207, 237, 263, 286.)

Y alloy, Duralumin, Alclad, aluminium-silicon alloys, aluminium-magnesium alloys, and aluminium-zinc alloys are reviewed. Their mechanical and other properties, including machining characteristics, are given.

MEASURING METHODS, INSPECTION.

Magnetic Particle Method of Inspection. (*Machinery,* 21*st February,* 1946, *Vol.* 68, *No.* 1741, *p.* 240.)

At present it would appear that the variables encountered in applying magnetic particle inspection are too numerous to allow a fully classified code of pro-

cedure to be formulated. From the results of investigations by A. V. de Forest and C. E. Betz it seems that the dry method is more sensitive than the wet, and that continuous current is more sensitive with regard to sub-surface faults than alternating current. Sensitivity is also increased by increase in the magnetizing current. Another factor is the size of powder particle. As a general proposition, the circular method of magnetizing, when it can be used, is to be preferred because the field is more or less contained within the component being tested. Magnetic-particle inspection may have a valuable application in the inspection of tools, such as large blanking dies requiring several hundred hours to make. In hob and milling-cutter inspection, the method is advocated using fluorescent particles. It is not always necessary to have elaborate equipment to apply the magnetic-particle test.

Inspection Records Aid Production. (*The Machinist*, 2*nd March*, 1946, *Vol.* 89, *No.* 47, *p.* 2449.)

A central office is used to formulate inspection instructions, compile and issue data sheets to the inspectors, to co-ordinate and analyse the data obtained on the completion of a run, and to make the results of this available to other departments concerned. The system is followed through from the start of a job, and the necessary forms are illustrated.

PLASTICS

Machining Laminated Plastics, by A. J. T. Eyles. (*Mechanical World*, 1*st March*, 1946, *Vol.* 119, *No.* 3087, *p.* 229, 13 *figs.*)

Generally the methods used for machining laminated plastic are those used in metal working, but there are fine points of difference. Recommendations including tool shape, and speeds and feeds are given for lathe tools, drills, trepanning tools, punching tools, taps and milling cutters.

Machining Plastics—Part II, by Richard M. Lane. (*Machine Production, January*, 1946.)

This article deals with threading and gives recommendations for internal and external work. Rake angles on taps and dies, chamfer and sizes of tapping holes are among the points referred to. Milling and kindred operations are also discussed.

(*Communicated by Machine Shop Magazine.*)

RESEARCH.

Single Point Turning Research, by Joseph F. Allen. (*The Iron Age*, 10*th January*, 1946.)

The first portion of a two-part article based on a lecture given to the A.S.M.E. Equipment is described for determining effect of cutter shape on cutting force components, power requirements, cutter life, and surface finish. Observations were made on turret and centre lathe turning and boring mill work. In the instance of the turret lathe, a machine normally having a top speed 920 r.p.m., and 15 h.p., had a drive which provided over 5,000 r.p.m. and 100 h.p. to avoid any restrictions caused by power and speed limitations. A Schiess-Defries pressure dynamometer was employed to record the components of the cutting force acting on the tool.

(*Communicated by Machine Shop Magazine.*)

Meter and Instrument Jewels and Pivots, by G. F. Shotter. (*The Journal of the Institution of Electrical Engineers, February*, 1946, *Vol.* 93, *Part II, No.* 31, *p.* 15, 19 *figs.*)

With a view to obtaining a more fundamental knowledge of the phenomena relating to meter and instrument bearings and to improving such bearings, research has been carried out with the sapphire/steel combination, both dry and lubricated, and other combinations of materials. The apparatus and methods of test are outlined, followed by a survey of the results from life tests, including an analysis of the various factors which contribute to wear. The results of a microscopical examination of the units at the end of their life run are discussed. A brief theory of the boundary lubrication existing in such bearings is given. Mathematical formulae developed during the research have been simplified into nomograms. The results of experiments on the resistance of sapphire jewels to impact forces are given. The phenomena associated with bottom bearings at various loads, caused by parasitic forces existing in meters, are also dealt with. The actions of the ball-type bearing and that of the pivot bearing are compared, and an approximate estimation of the life of bearings in practice, based on life tests, is made.

SMALL TOOLS.

Efficient Hob Sharpening, by P. B. Ward. (*Machine Shop Magazine, March*, 1946, *Vol.* 7, *No.* 3, *p.* 36, 14 *figs.*)

Part I. The various points that must be watched in sharpening a hob are: uniform run-out over entire hob, run-out on each side of hob 180 deg. apart, run-out on one side of hob only, cutting face ground with incorrect lead, cutting faces unequally spaced, cutting face ground with hook and not radial, cutting faces ground negative and not radial, cutting faces unequally spaced on multiple-thread worm hob, and variation of helix angle under repeated sharpening. The results of these errors and how to avoid them are thoroughly discussed. Of all the various types of hobbed work probably the one most sensitive to errors is the parallel-key spline shaft, and this is given special consideration.

SURFACE, SURFACE TREATMENT.

Surface Condition of Metals. (*Sheet Metal Industries, February*, 1946, *Vol.* 23, *No.* 226, *p.* 338, 2 *figs.*)

Abstracts are given from papers presented in Paris in October by La Commision Technique des Etats et Propriétés de Surface des Métaux. The papers were as follows:—

The Elektron Microscope and Its Application to the Study of Surface Conditions, by Professor Dupuoy.

In the examination of the infinitesimal, the application of the ordinary microscope is limited. Recent work has shown that electrons can be diffracted, behaving as though controlled by associated wave systems. In the electron microscope, electrons are produced by a filament at a high temperature. The first magnetic lens is the condenser; a second one produces the first image; and a third, called the projection lens, produces the final image. Surfaces cannot be examined directly. One solution has been obtained by producing thin oxide films on the metal and then removing them by chemical means. The other consists in making extremely thin replicas of the metallic surface. A technique which seems to give the highest resolution of surface detail is that of using polystyrene as negative material and a thin film of silica as final replica.

The Study of Metal Surfaces by Electrolytic Means and the Part Played by the Beilby Layer, by Professor Grumbach.

The author gave the results of potential measurements between platinum electrodes in a dilute solution of potassium dichromate. The value of V_0 is dependent on the solvent employed. The author stated that it was his belief that the solvent molecules are stratified on the electrodes.

Comparison of Electro-Chemical and Electronic Investigations of the Beilby Layer, by Dr. M. Taboury.

The author made use of both electro-chemical analysis and electron microscopy, and gave evidence of the occurrence of the Beilby Layer derived from studies of the metal/solution condition.

Anodic Oxidation as a Means of Investigating the Superficial Structure of Aluminium and Its Alloys, by Dr. P. Lacombe and M. L. Beaujard.

The authors indicated that anodic oxidation provided a new etching technique for macro and micro examination. They were able to use the uniformity of the film thickness to determine the surface profile, the oxide layer giving an excellent print of the surface. Profile determinations were used to examine the layer cross-section.

The Development of Electrolytic Polishing, by Dr. P. Jacquet.

After a short historical review of the development of this process, the author indicated that considerable progress had been made. It is now possible to maintain the geometrical shape of the component treated and to control the thickness of the metal which is removed. He gave a complete survey of the applications of the process, including micrographic examination, corrosion research, micro hardness and fatigue tests. He also indicated some new industrial applications such as super-finishing by electrolytic polishing of mild steels and carbon steels before plating. The electrolytic polishing of aluminium, brass, mild steels, carbon and alloy steels is coming into use in French industry.

Electrolytic Polishing as a Process of Super-finishing, by Dr. Mondon.

The author first gave a short review of the different mechanical finishing processes, such as grinding, honing, lapping, super-finishing, and indicated that electrolytic polishing was superior in several respects. He pointed out that this process was likely to be of considerable importance in the finishing of engineering components. Research was carried out in industrial baths for polishing carbon and alloy steels, the shape of the components being maintained with great accuracy. For example, an axle with a surface roughness of 50 mu. in. electrolytically polished for 30 seconds corresponds to a loss of metal of 0·004 in., with a finish of about 5 micro inches. Good results had also been obtained on gears and springs. Finally, electrolytic polishing was stated to be very valuable for revealing superficial defects such as grinding cracks, quenching cracks, etc.

The Development of Electrolytic Polishing in Great Britain, by Dr. S. Wernick.

There is intense interest in the possibilities of electrolytic polishing in Great Britain, in view of the acute difficulties encountered at present in mechanical polishing. The author described experiments which he had carried out on the electrolytic polishing of stainless steels, and he compared the phosphoric acid and sulphuric acid processes as employed in America, indicating the advantages and disadvantages of each. The author discussed the possibilities of employing auxiliary mechanical polishing together with electrolytic polishing where completely satisfactory results are not obtainable by the latter process, and finally indicated that there is a strong possibility that electrolytic polishing will replace mechanical polishing in many fields.

Microgeometry of Surfaces, by M. Michalet.

The author described a recording diffusiometer. In this instrument a beam of light falls on the metal surface to be examined at an angle of 45 degrees. The diffused rays, which are reflected in different directions, are received by a photo-electric cell which records the current passing. Another apparatus was also described, known as the "Portemètre" apparatus, which is based on the following principle: The total reflection which occurs on the hypotenuse face of a prism disappears at a point where this face is in contact with the metallic surface. By examining the contact line of a cylindrical axle on the prism with a microscope, black lines are observed which correspond to the contact points with the axle surface. The contact appears to be a continuous line provided that the striations on the piece do not exceed a few micro inches in depth.

Surface Measurement, by R. E. Reason.

The author dealt with the principles which underly stylus methods of measuring surfaces, differentiating between the rounded and pointed stylus. Investigations had shown that the most difficult problem of graphical representation was to provide a satisfactory datum relative to which the movements of the stylus could be measured. The problem of arriving at a numerical assessment of the surface irregularities had been tackled and it had been found that modern instruments were selective in their performance. To facilitate the use and construction of instruments it was proposed that the range should be divided into an agreed number of steps, each of which could be designated by a letter.

Measurement of Surface Roughness, by C. Timms.

Various types of instruments have been developed and are in use in industry. These instruments were briefly described, with details of the range of roughness which each can accommodate. There is need for correlation between the physical and geometrical aspects of surfaces, in order to evaluate their properties accurately. The calibration of instruments of this type presents some difficulty in view of the high ranges of magnification involved. To meet this need, standards of known roughness have been developed at the National Physical Laboratory. The author also described the methods used for establishing a rational specification for surface roughness. This review indicates that no one method alone provides an adequate measure of all the essential qualities of a surface and quite possibly different methods will need to be used in accordance with the function for which the surface was prepared.

The Use and Interpretation of the Correlogram, by J. R. Womersley and M. R. Hopkins.

The paper centred round a suggestion for the use of the correlogram in the interpretation of the surface finish records. According to this, modern surface finish measuring instruments of the stylus type provide a graphical record of the profile of a machined surface and also a reading on a meter indicating the extent of the departure of the profile from a centre line. This reading does not completely specify the profile, and the surface must be judged by considering also the graphical record. The paper suggests that the nature of the surface as shown by the record can be conveniently described by the use of the correlogram, and examples where this has been done are cited. The correlogram and its use were described. The authors propose to investigate a number of surfaces in this way as part of the Research programme of the National Physical Laboratory in order to see whether the correlogram is sensitive enough to distinguish between different surfaces and provide a useful description of the form of their profiles.

Relation Between the Coefficent of Friction and Surface Finish, by Dr. Marcelin.

He described apparatus for the instantaneous measurement of the friction coefficient under varying conditions. The measurements were chiefly made in

order to study lubricants and, in particular, the formation and breakdown of oil films on bearings.

The Influence of Surface Finish on Hardness Tests, by Professor Bastien.

The author concluded as follows: The Herbert pendulum method gives accurate results independent of surface roughness, particularly on soft metals where the scratches are rubbed off by the motion of the pendulum ball. Although this test is a very superficial one, the results are reasonably constant. The Vickers test gives values which are independent of surface roughness when the indentation size is related to the degree of roughness; and finally, hardness tests obtained by measuring the depth of penetration are unsuitable for testing rough metal surfaces.

WELDING, ETC.

Metallurgical Features in Welded Steels, by Hugh O'Neill. (*Transactions of the Institute of Welding, February,* 1946, *Vol.* 9, *No.* 1, *p.* 3, 14 *figs.*)

Conditions affecting the weldability of high stength steels are reviewed. A progress report is given on a new simple weld ductility test. From a study of the welding of steel as conducted both in the primitive smith's hearth and by modern non-fusion processes, a critical definition of the art is suggested. This definition would distinguish in principle between bonding effects due to true welding and adhesion effects such as those which occur between loaded metallic surfaces in rubbing contact. The fusion welding of ordinary steels is next considered with reference to the curious local hardening produced in ferrite by "stray flashes." Wöhler fatigue tests on a low alloy steel intentionally provided with these hard spots indicate the danger of such isolated arc craters in structures subjected to dynamic stresses.

The Welding of Non-Ferrous Metals, by E. G. West. (*Sheet Metal Industries, March,* 1946, *Vol.* 23, *No.* 227, *p.* 553, 10 *figs.*)

Part VII. Resistance welding of aluminium alloys. The specific requirements of aluminium and its alloys, effect of the oxide film, current requirements, suitable welding machines, and metallurgical characteristics are first discussed. The technique of preparation and welding is then described in detail, including preparation of the surface, by mechanical or chemical means, machine setting and production data, cooling, cleaning and trimming of tips, and the relation between variables and welding strength.

Pressure Welding, by H. Herrmann. (*Welding, March,* 1946, *Vol. XIV, No.* 3, *p.* 120, 9 *figs.*)

Production of light alloy charge-cooler elements was carried out in Germany by pressure welding. Pressure welding of aluminium is carried out in the plastic condition of the material with high pressure, and leaves no cast structure behind. The theory of the process, the welding dies, welding time, cleaning the sheet, prevention of sticking, starting-up, sources of flaws, weld seam faults, and the applicability of the process are described.

Friction Welding, by Kenneth Rose. (*Welding, March,* 1946, *Vol. XIV, No.* 3, *p.* 132, 2 *figs.*)

A new method for joining thermoplastics can also be used for joining plastics with other materials.

Electricity Power Stations, by D. G. Sinfield. (*Welding, March,* 1946, *Vol. XIV, No.* 3, *p.* 109, 20 *figs.*)

Part II. Procedure and the fabrication of heavy plant are described.

Tubular Members, by I. H. Hogg. (*Welding, March,* 1946, *Vol. XIV, No.* 3, *p.* 104, 6 *figs.*)

Methods of preparation for welding are described. The advantages of tubular structures are indicated. Particular attention is paid to the use of templates on a nibbling machine.

Controlling Distortion in the Gas Welding of Sheet Metals, by C. G. Bainbridge. (*Sheet Metal Industries, February,* 1946, *Vol.* 23, *No.* 226, *p.* 356, 10 *figs.*)

The most important factors producing distortion are: the heating and cooling of the metal adjacent to the joint, the cooling shrinkage of the weld metal, unsuitable type or location of joint, or faulty preparation of the welding edges, and faulty welding procedure or blowpipe manipulation. The effect of weld shrinkage is usually of less importance than the effects of expansion, and contraction and buckling can be minimised if the heat necessary for welding is confined to a narrow zone along the joint edges, *e.g.*, by jigs. The factors in the design and location of joints are thoroughly discussed. The butt joint usually is the most satisfactory. Corner joints may be employed satisfactorily, but tee and lap joints are to be avoided. Welding procedure including blowpipe manipulation, maintaining edge alignment, and the use of jigs are also discussed.

Resistance Welding of Heat-Resisting Materials, by H. E. Lardge. (*Aircraft Production, March,* 1946, *Vol. VIII, No.* 89, *p.* 107, 18 *figs.*)

The metallurgical factors and welding technique involved in spot, stitch and seam welding of sheet material in annealed 18/8 austenitic stainless steel, Inconel and an 80/20 nickel-chromium alloy, in thicknesses varying from 16 to 26 S.W.G. are discussed. The high resistivites and low heat conductivities allow these materials to be welded with less electrical energy than is used for mild steel and with the high coefficients of expansion which increase the danger of distortion it is most desirable that short welding times be used. For stitch and seam welding, full electronic-valve controllers should be used. Underwater welding reduces distortion to a minimum and reduces electrode "pick-up." Underwater welding helps in reducing the danger of forming undesirable carbides in austenitic steels. It is essential that the material be as clean as possible. Cleaning can be accomplished by pickling, scratch-brushing, or cleaning with emery-wheels or cloth. Desirable welding conditions are indicated, with a method for obtaining satisfactory machine settings. Practical points for spot, stitch and seam welding are fully discussed and micrographs of different welds are shown.

Oxyacetylene-Cutting Tactics for Various Alloy Steels, by Dr. G. V. Slottman. (*The Machinist,* 16*th March,* 1946, *Vol.* 89, *No.* 49, *p.* 2542, 4 *figs.*)

Some steels can be cut cold, but others require preheating. The correct cutting procedures are described.

Stack Cutting of Thin Sheets Produces Parts of Identical Contour, by Dr. G. V. Slottman. (*The Machinist,* 9*th March,* 1946, *Vol.* 89, *No.* 48, *p.* 2490, 6 *figs.*)

Methods of aligning, clamping and starting cuts on stacks of plates and sheets are reviewed.

Soft Solders and Soldering Technique, by L. C. Earle. (*Sheet Metal Industries, March,* 1946, *Vol.* 23, *No.* 227, *p.* 515, 7 *figs.*)

Part I. The author deals with the history and properties of soft solders, and with the fundamentals of joint formation and solder penetration.

WORKS AND PLANT.

The Fire Hazard in Plant Maintenance, by W. M. Gore. (*Mechanical World,* 22*nd March,* 1946, *Vol.* 119, *No.* 3090, *p.* 321, 1 *fig.*)

Some points about precautions and notes on the care of the extinguishers and their operation.

INDEX TO ADVERTISEMENTS

As a war-time measure the advertisement section of this Journal is now published in two editions, A *and* B. *Advertisers' announcements only appear in one edition each month, advertisements in edition* A *alternating with those in edition* B *the following month. This Index gives the page number and edition in which the advertisements appear for the current month.*

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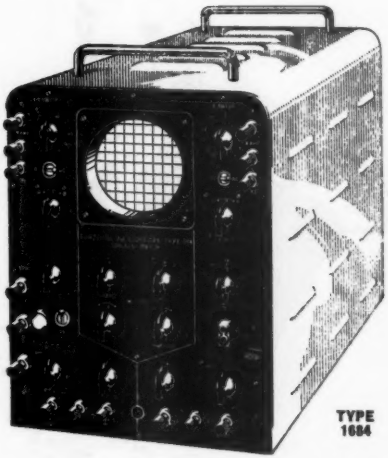

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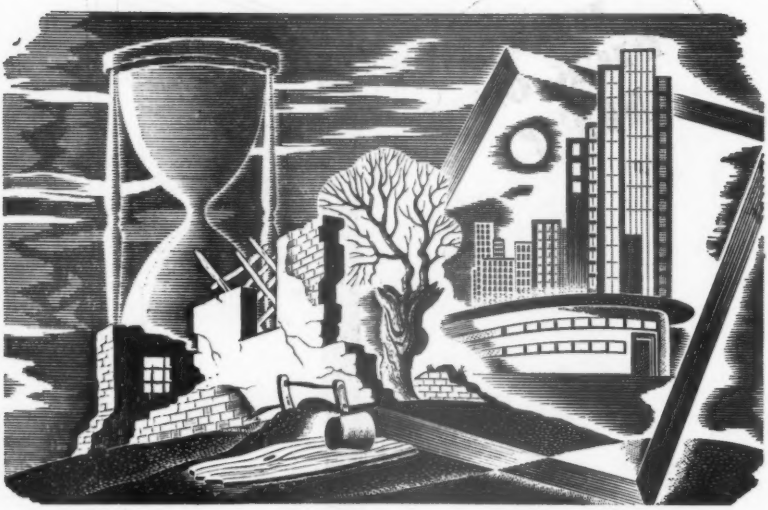

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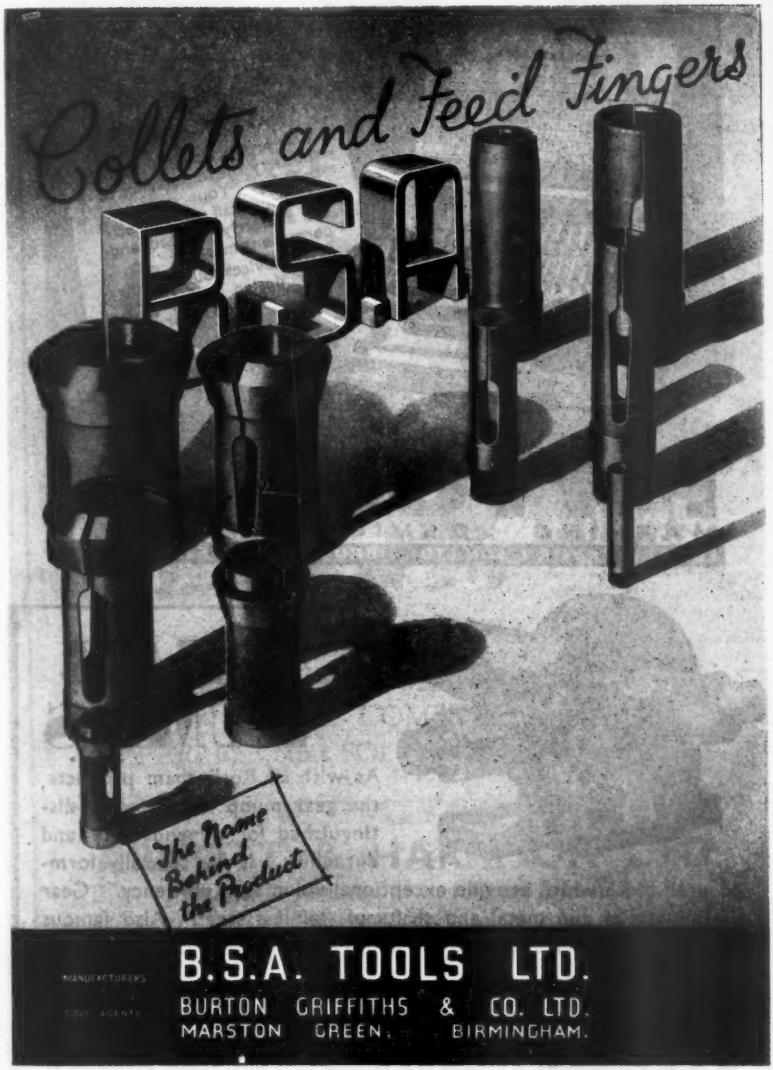
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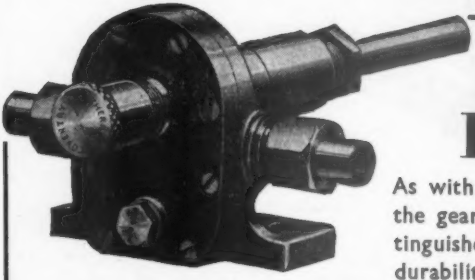

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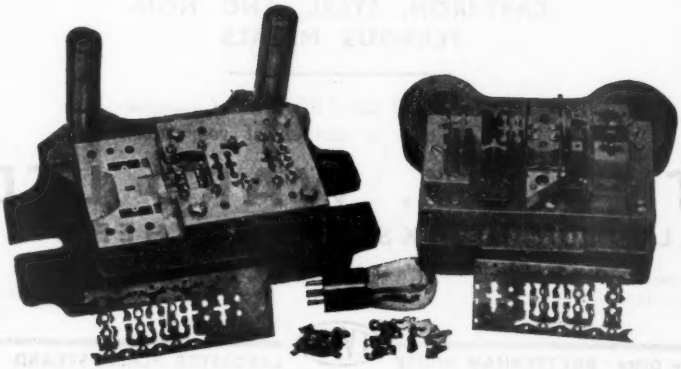

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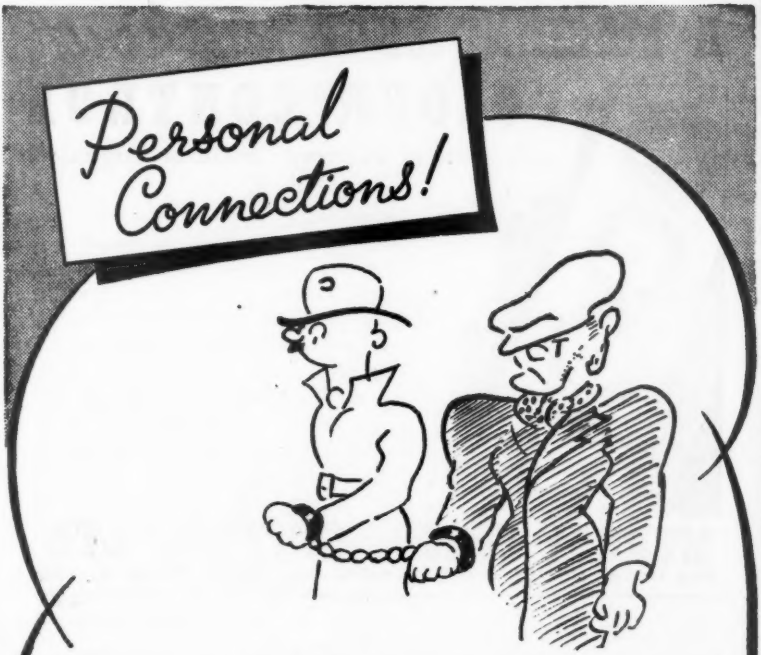

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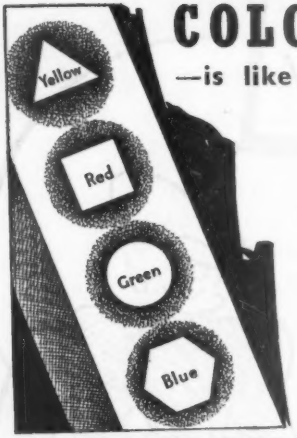

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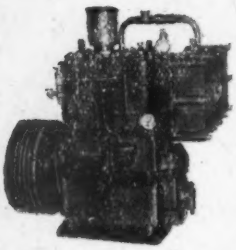

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